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COSMIC GAMMA-RADIATION FROM PION DECAY: COMMENTS ON A PAPER BY CAVALLO AND GOULD

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Cosmic Gamma-Radiation from Pion Decay: Comments on a Paper by Cavallo and Gould.

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Summary: There is a discrepency between previously published results and those of Cavallo and Gould on the calculated gamma-ray production spectrum arising from the decay of neutral pions produced by cosmic ray interactions with interstellar gas. This discrepency is reexamined here with the conclusion that Cavallo and Gould have overestimated the gamma-ray production rate from this process in their recent paper.

Within the past decade, several calculations have been made to determine the production of cosmic gamma-rays from cosmic-ray interactions in the galaxy ([1-4]) because of the inherent importance of these calculations to cosmic-ray astrophysics. These calculations have been based, for the most part, on accelerator data on p-p interactions which have been available for some time and have, until recently, been consistent in their conclutions. However, the most recently published results, those of Cavallo and Gould ([4]), are in our opinion enough in disagreement with previous

calculations to warrant some further comment. Previous calculations ([1-3]) based on measured cross sections for neutral pion production in p-p interactions have placed the gamma-ray production rate for energies above 50 MeV at $\sim 1 \times 10^{-26}$ $cm^{-3} sec^{-1} sr^{-1}$. The recent calculation of Cavallo and Gould ([4]) indicates a production rate at almost twice that value. Also, a relatively less important discrepency may be found in the shape of the gamma-ray production spectrum as calculated by Cavallo and Gould ([4]) as compared with those previously calculated ([2,3]). Cavallo and Gould have obtained a flatter spectrum than those previously calculated which, they claim, must be correct on the basis of "elementary reasoning" based on kinematical arguments which they present at the beginning of their paper. These arguments are based on the well-known principle that the high threshhold energy for pion production places kinematical restrictions on pions directly produced in the cms of the interaction resulting in minimum velocity for these pions in the laboratory system. The result is a flat-topped gamma-ray spectrum. However, this elementary argument does not hold for pions produced by the decay of isobars moving backward in the cms and therefore close to rest in the laboratory system. Under the assumption that a significant fraction of pions are produced in this manner, an assumption argued for on the basis of accelerator data in references 2 and 3, a more rounded spectrum is obtained. The resultant spectra given in references 2 and 3, which are in good agreement with each other, substantiate this conclusion.

It appears that both the flatness of the spectrum obtained by Cavallo and Gould and the higher production rate which they obtain are due to what they claim to be a contribution from a direct double π^0-production channel which they imply that we did not include at all in our calculation

([3]). However, this channel was included implicitly in the curve which was given in reference 3 for the average π^0-multiplicity as a function of energy which includes the average effect of all channels. As an example, we may quote the very recent accelerator results of the Scandinavian bubble chamber group ([5]) for p-p interactions at 19 GeV/c who obtain an average cross section times multiplicity for π^0-production of 41.7 mb whereas we gave 42 mb in reference 3.

There are only two references in the literature giving cross sections for the direct two-pion production process ([6,7]) both of which are not new and both of which indicate that this channel contributes less than 10% of the total neutral pion production at energies up to 2 GeV. Thus, we feel, there is no evidence at present that any important production channel has been neglected by previous workers in estimating total gamma-ray production in cosmic-ray interactions. It is our conclusion that Cavallo and Gould have overestimated the gamma-ray production rate in cosmic-ray interactions and that the results given by previous workers should be considered a more accurate estimate for astrophysical applications.

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